An Interdigitated Coupler with Defect Ground Structure

Jing Zhang, Zhaoxiang Wu, Feng Xu and Dandan Li

School of Electronic Science and Engineering
Nanjing University of Posts and Telecommunications, Nanjing 210003, China
Email: feng.xu@njupt.edu.cn

***Abstract* — In this paper, an interdigitated coupler with defect ground structure in the coupling position is presented. Compared to the conventional interdigitated coupler, the proposed coupler loosens restrictions of the coupling-line width and space between coupling lines. As a result, the requirement of fabricating accuracy for the new coupler is lowered. In addition, with the introduction of suitable defect ground structure, the bandwidth of the coupler can be improved substantially. The designed 3-dB coupler has the coupling strength of -3dB±0.8dB within the passband of 2~8GHz, while both the isolation response and the return loss are lower than -20dB.**

Index Terms — Defect ground structure, interdigitated coupler, wideband.

I. Introduction

As an indispensable component in most microwave system, microwave couplers have been widely studied with the development of microwave science, they are used for power dividing and combining, sampling, signal injection and power monitoring in microwave communication sub-systems and radar [1]. The branch-line couplers for tight coupling such as 3-dB or 6-dB can be easily implemented in a conventional way, but design of loose coupler is quite different in this way [2] for high impedance branch line required. For coupled-line coupler, parallel-line couplers only suit for loose coupling as coupling strength lower than 8-dB [3], broadside-coupling couplers can obtain 3-dB coupling or more tighter coupling, but the feed ports of the couplers locate in different layers [4-6]. Lange couplers or interdigitated couplers can achieve tight coupling and broad wideband, but a small coupling-line width and small spacing between coupling lines is required, thus the bond-wire based on such small space is challenging to realize in practice [7]. In order to overcome the contradiction of application and manufacturing, much effort has been done during these years.

The defect ground structure (DGS) is an etched periodic or non-periodic cascaded configuration in ground of a planar transmission line which disturbs the shield current distribution in the ground plane cause of the defect in the ground. This disturbance will change characteristics of a transmission line such as line capacitance and inductance. As high performance, compact size and low cost often meet the stringent requirements of modern microwave communication systems, new technologies and new structures including DGS have been used to enhance the whole quality of system. Usually, the transmission lines with DGS have much higher impedance and increased slow-wave factor than conventional lines. In [2], DGS is employed to generate high impedance line for loose branch-line coupler. In [8], DGS is used to microstrip forward-wave coupler for size–reduction. In fact, DGS have been widely used from the concept put forward for its multi advantages including good high frequency characteristics.

In this paper, a 3-dB interdigitated coupler is implemented with DGS in the coupling position. Compared to the conventional interdigitated coupler, the proposed coupler with DGS has weaker restriction to the coupling-line width and spacing between coupling lines. Under the same circumstance, the coupling line width improves from 0.22mm in the conventional interdigitated coupler to 0.62mm in the proposed coupler with DGS, and the spacing between coupling lines improves from 0.08mm to 0.22mm. In addition, a suitable DGS can substantially improve bandwidth of the coupler. The designed 3-dB coupler obtains coupling strength of -3dB±0.8dB within passband in 2~8GHz, both isolation response and return loss below -20dB.

II. Design Example and Analysis

As interdigitated coupler is often used when a strong coupling is required, we synthesize the 3-dB coupler for example. For comparison, we firstly design a conventional interdigital coupler which is depicted in Fig.1. The black lines represent bond-wires, the profile of the bonding wires is assumed to conform to cosine function. The substrate of choice is 0.5-mm-thick Rogers R04003c with a permittivity of 3.38. The 50-Ohm feeding lines are extended for easy measurement with coaxial adapters. With the help of a commercial finite-element-method package HFSS, the simulate results are showed in Fig. 2.

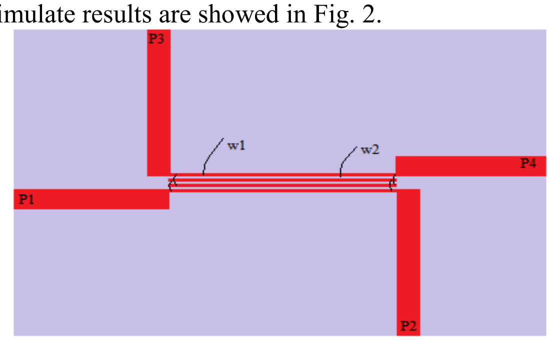


Fig 1. Conventional interdigitated coupler.

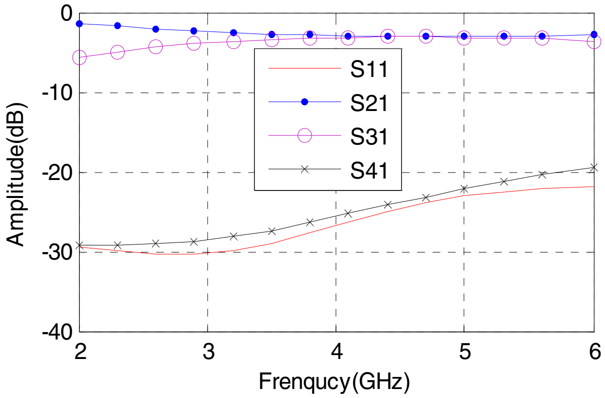


Fig.2 Simulation results.

The coupling line width is 0.182mm, the space of coupling lines is 0.08mm. Experiences tell that it is mostly imposible to weld bond-wires based on the line when line-width lower than 0.8mm manually. So the use of conventional interdigitated coupler faces difficulty in practice.

Next, we will show the proposed interdigitated coupler with defect ground structure in Fig.3. We hold the material and thickness of the substrate the same as 0.5mm thick Rogers R04003c for comparision. The sketch is the same as the conventional interdigitated coupler shown as Fig.1 except there is defect ground structure in the center of coupling position.

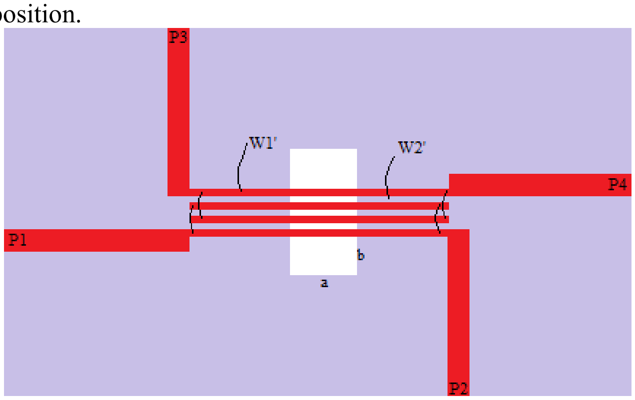


Fig.3 Interdigitated coupler with DGS.

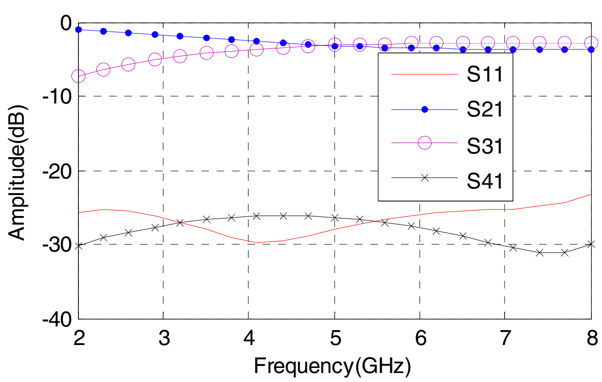


Fig.4 Simulation results.

The simulation result obtained from HFSS will be showed in Fig.4. As Fig.2 and Fig.4 shows, we can find that the coupling strength of the two kinds of couplers almost the same, the coupling-line width is 0.602mm, the spacing between coupling lines is 0.202mm. This makes the implement of welding bond-wire practical.

To validate the rationality of the proposed interdigitated coupler with DGS, a prototype is fabricated as Fig.5 shows.

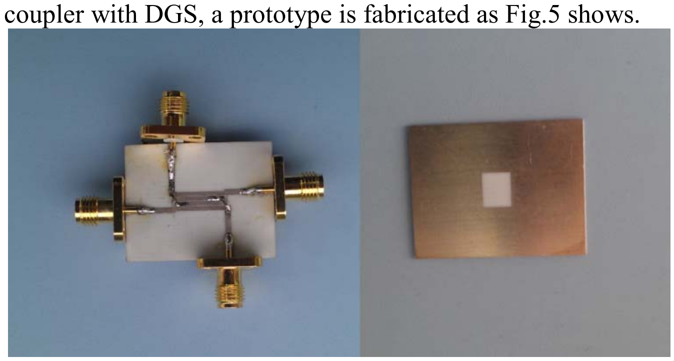


Fig.5 fabricated prototype.

The measure result is shown in Fig.6. As the figures illustrate, to a great extent, the measure results match the simulation results.

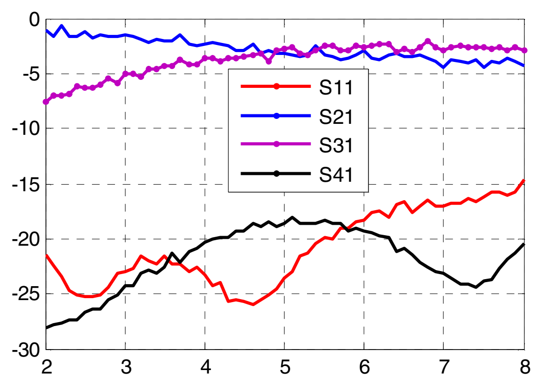
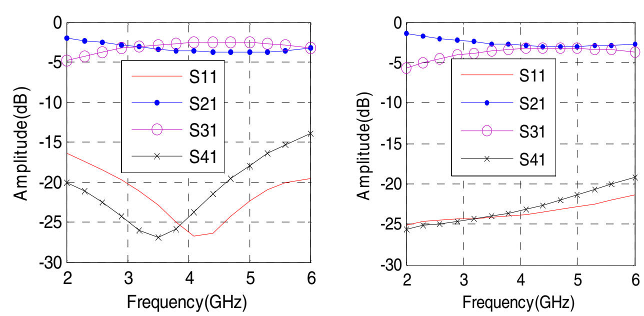
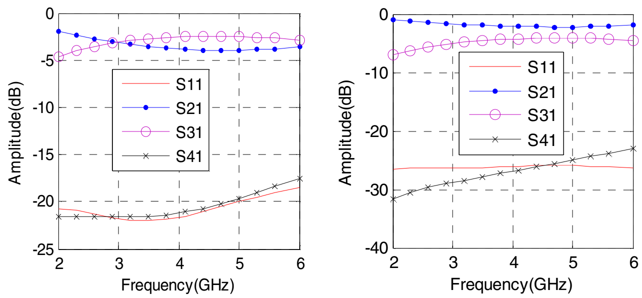


Fig.6 Measured results.

Next, we will investigate the difference of the interdigitated coupler with DGS or without when manufacturing error happens. Suppose the manufacturing line common difference as ±0.02mm, Fig.7 shows the different results from Fig.2 of conventional interdigitated coupler, and Fig.8 shows the different results from Fig.4 of the proposed interdigitated coupler with DGS.

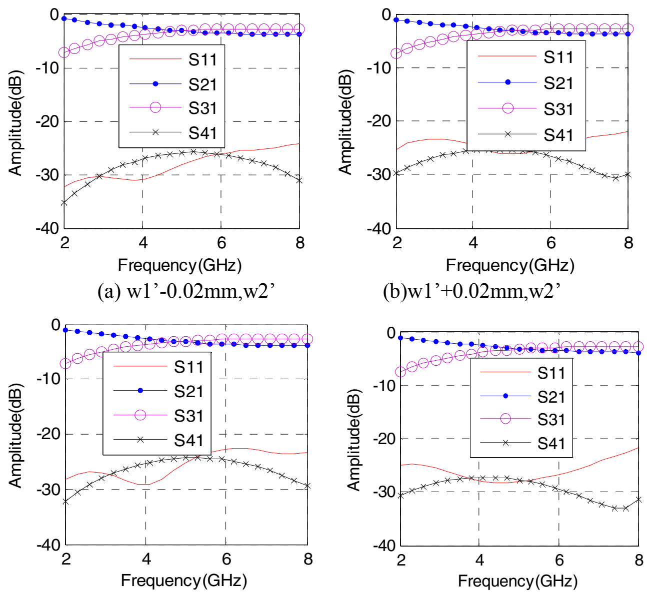


(a) w1-0.02mm,w2 (b) w1+0.02mm,w2



(c) w1,w2+0.02mm (d) w1,w2-0.02mm

Fig.7 Influence of manufacturing error of conventional coupler.



(a) w1'-0.02mm,w2' (b)w1'+0.02mm,w2'

(c)w1',w2'-0.02mm (d) w1',w2'+0.02mm

Fig.8 Influence of manufacturing error of the proposed coupler.

From the two set of results showed in Fig.7 and Fig.8, we can see the meaning of the proposed interdigitated couplers with DGS. In fact, we choose the same substrate, and the objective coupling strength is both 3dB, when manufacturing error of 0.02mm happens, the coupling strength of conventional coupler may change significantly.

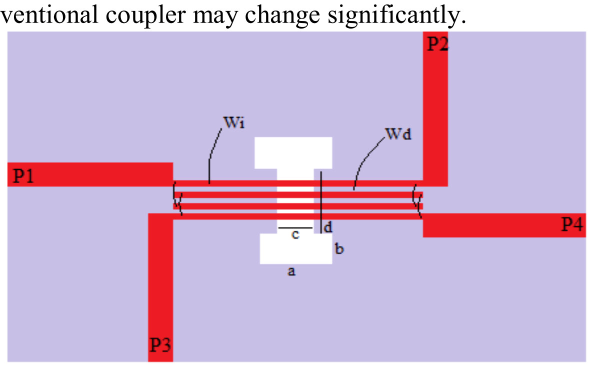


Fig.9 Interdigitated Coupler with DGS.

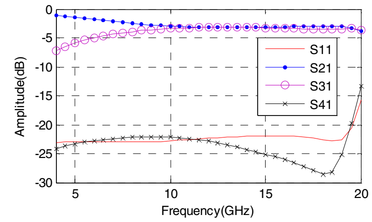


Fig.10 Simulation result.

To make a further validation of the rationality of the proposed interdigitated coupler with DGS, we will give another example as Fig.9 shows. The substrate of choice is 0.5-mm-thick RT/Duroid 6002 with a permittivity of 2.94. The parameters of the sketch are as follows: w_i =0.22mm, w_d =0.106mm, a=1.92mm,b =0.5mm, c= 1.04 mm, d=1.98mm. The simulated results are showed as Fig.10.

III. Conclusion

This paper presents a kind of interdigitated coupler with DGS in the coupling position. Compared to the conventional Lange coupler, interdigitated coupler with suitable DGS has weaker restriction to the coupling-line width and spacing between coupling lines. As a result, manufacturing error has a lower influence to the coupling strength. In addition, the presented coupler with DGS can improve bandwidth substantially.

Reference

[1] Bialkowski M E, Seman N, Leong M S. Design of a compact ultra wideband 3 dB microstrip-slot coupler with high return losses and isolation. Microwave Conference, 2009. APMC 2009. Asia Pacific. IEEE, 2009: 1334-1337.

[2] Moyra T, Roy A, Parui S K, et al. Design of 10 dB branch line coupler by using DGS. Communications, Devices and Intelligent Systems (CODIS), 2012 International Conference on. IEEE, 2012: 516-519.

[3] Pozar D M. Microwave engineering. John Wiley & Sons, 2009.

[4] You S J, Liao W. A multi-layer coupled-line power divider. Antennas, Propagation and EM Theory, 2008. ISAPE 2008. 8th International Symposium on. IEEE, 2008: 675-678.

[5] Abbosh A M. Design of ultra-wideband three-way arbitrary power dividers. Microwave Theory and Techniques, IEEE Transactions on, 2008, 56(1): 194-201.

[6] Ghazali S, Seman N, Yob R C, et al. Design and cross-section analysis of wideband rectangular-shaped directional coupler. RF and Microwave Conference (RFM), 2011 IEEE International. IEEE, 2011: 161-165.

[7] Presser A. Interdigitated microstrip coupler design. Microwave Theory and Techniques, IEEE Transactions on, 1978, 26(10): 801-805.

[8] Hosseini S A, Atlasbaf Z, Forooraghi K. Two new loaded compact palnar ultra-wideband antennas using defected ground structures. Progress In Electromagnetics Research B, 2008, 2: 165-176.